1D var retrievals of dust contaminated radiances

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Outline

- Improve AIRS retrieval products by including dust as a retrieved variable
  - Easiest to do this using cloud cleared radiances
  - BUT nonuniform dust will be removed from the radiances, so this would lead to physically inaccurate dust optical depths
- Science topics : Dust Transport
  - will need optical depths and particle sizes
  - needs retrievals on individual FOVs and lots of quality control
  - Hidden retrieved variable?
- Science topics : OLR forcing for climate
  - AIRS is excellent instrument for longwave OLR dust forcing
  - could be an active climate change variable
  - needs good SST, so needs individual FOV dust retrievals

Dust and AIRS radiances

- AIRS has sensitivity to dust spectral signatures
- AIRS radiances can provide day and night :
  - dust detection over ocean and land
  - retrieval of optical depths
  - dust OLR forcing
  - AIRS can retrieve dust over sunglint regions (MODIS has problems)
- Significant fraction (10%) of AIRS observations dust contaminated, including Atlantic during hurricane seasin
- Examining AIRS L2 products shows retrievals avoid dust regions, produce erroneous results and/or do not retrieve all the way to the surface

Retrieval of Dust Optical Depths Over Ocean and Land

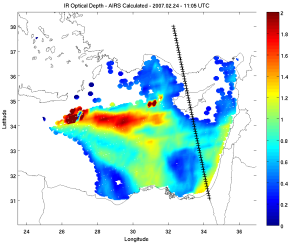
- use SARTA (PCLSAM : Chou et al, AMS Jan 1999 pg 159) with adjusted SST (George Aumann) for sea and land
- uses Masuda emissivity for ocean
- uses Global Infrared Land Surface Emissivity Database (SSEC/U.Wisc) (E. Borbas, S. Wetzel-Seemann, R. O. Knuteson, P. Antonelli, J. Li and H.-L. Huang)
- retrieve only for FOVs tagged as "dust contaminated"

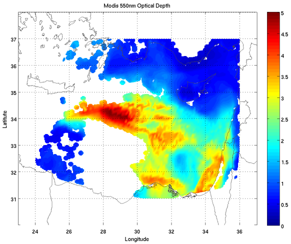
UMBC Dust Retrieval Methods

- FASTER method
  - uses ECMWF (or AIRS retrievals) for T(z),Q(z) fields
  - climatology or CALIPSO guess for *ptop*, use 2 um radius
  - weighted average of $BT_i^{obs} - BT_i^{calc}$, and $(BT_i^{obs} - BT_j^{obs}) - (BT_i^{calc} - BT_j^{calc})$ for selected set of thermal IR channels
  - use linear fit with SARTA CLOUDY to estimate cloud loading n
    $BT_i^{obs} = BT_i^{calc}(n) + \delta BT_i^{errors}$
  - very fast $\leq$ 1 second per profile
- SLOWER method
  - climatology or CALIPSO guess for *ptop*, use 2 um radius
  - uses ECMWF (or AIRS retrievals) for first guess T(z),Q(z) fields
  - 1d VAR method
  - much slower $\simeq$ 1 minute per profile

Optical Depths for Feb 24, 2007 duststorm

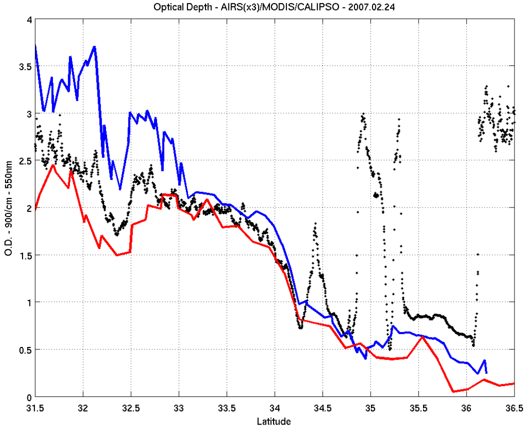
Calipso track overlaid on crosses
Left side : AIRS at 900 cm-1 ; Right side : MODIS at 0.55 um





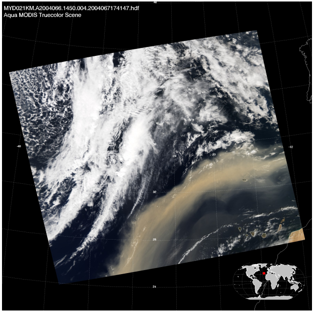
3 instruments on the A-Train (Feb 24, 2007 duststorm)

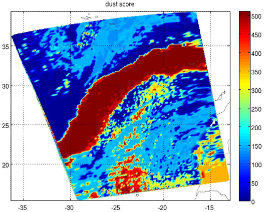
AIRS 10 um (x3), Calipso 0.55 um and MODIS 0.55 um optical depths retrieved along Calipso track



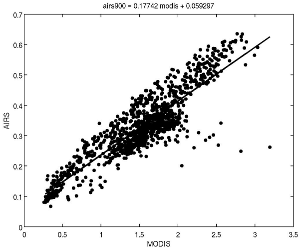
March 6, 2004 duststorm

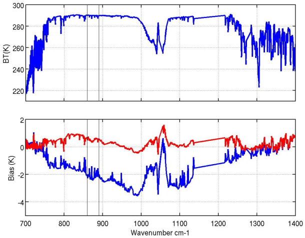
Left : True color MODIS image
Right : AIRS Dust flag





Optical Depth and Bias





AIRS infrared optical depths at 900 cm^{-1} plotted against MODIS Ch 2 (550 nm) visible optical depths, for dusttop at 600 mb. At 900 mb (1.0 km), $\frac{\tau_{AIRS}}{\tau_{MODIS}} \simeq$ 0.5

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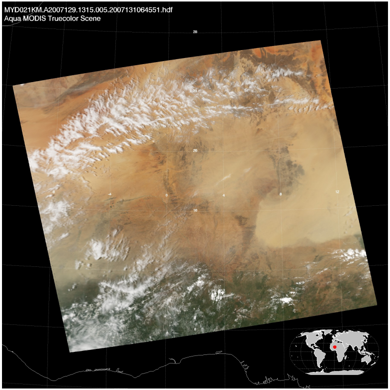
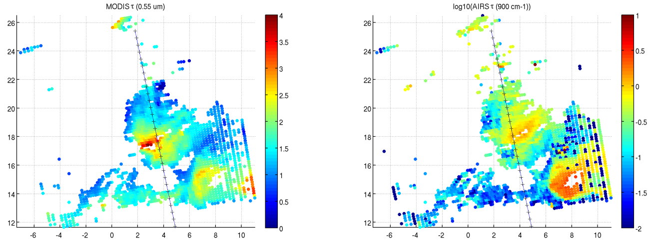
Retrievals Over Sahara : May 9, 2007

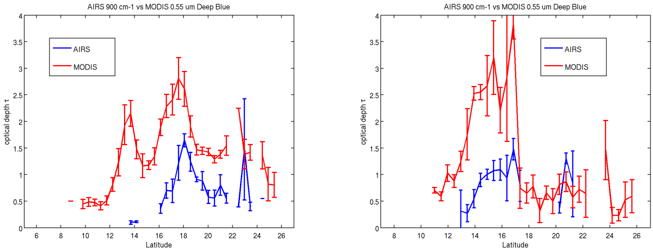


Retrievals Over Sahara : May 9, 2007



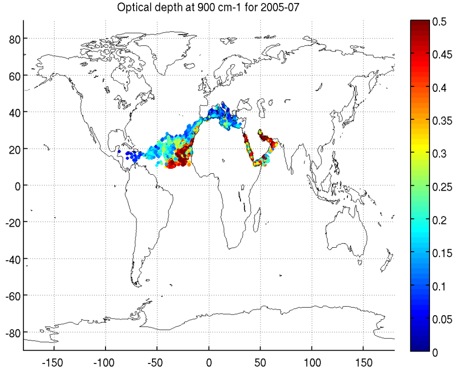
Left : MODIS
Right : AIRS
CALIPSO track shown as crosses
Dust flag over land needs LOTS of work!

Retrievals Over Sahara : Two cases (May 9, 10 2007)



Comparisons along CALIPSO tracks to MODIS Deep Blue for Saharan DustStorms in May 2007 (AIRS 10 um OD $\simeq \times$ 2 less than MODIS 0.55 um)

July 2005 uniform dust contamination



Dust that made it through spatial non-uniformity (tens of km) tests for July 2005. Shows summer dust contamination can extend to the Carribean

Effects of Dust on AIRS radiances and Retrievals

- Large duststorms can have uniform enough dust that makes it through "uniform clear" stage
- This could negatively impact AIRS retrievals

UMBC Retrievals

$$x_{i+1} = x_i + \left(S_a^{-1} + K^T S_\epsilon^{-1} K\right)^{-1} K^T S_\epsilon^{-1}(y_{obs} - y_i) - S_a^{-1}(x_i - x_a)$$
$$A = GK = \left(S_a^{-1} + K^T S_\epsilon^{-1} K\right)^{-1} K^T S_\epsilon^{-1} K$$

where
K = Jacobian (use SARTA-cloudy for each layer/cloud param
S_a = diaganol covariance matrix, whose terms are 1 K for temperatures, and log(1+0.1) for water amounts/cloud parameters
S_ϵ = diaganol matrix whose terms are on the order of 0.2 K

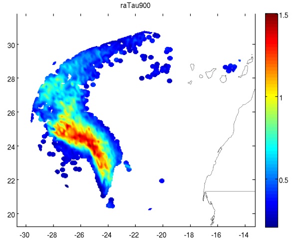
Channel list includes channels for 15 um for T(z) retrieval, 6 um for water(z) and 10 um window channels for lower atmosphere/surface/dust parameters

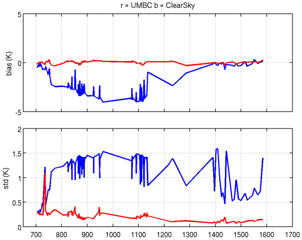
Comparing AIRS-L2 vs UMBC Retrievals vs ECMWF

- AIRS L2 retrievals chosen had Quality Flags set good or best for
  - Cloud_OLR
  - Temp_Profile_Bot
  - H2O
  - Surf (not used in some plots)
  - Guess_PSurf
- UMBC retrievals used Optimal Estimation to simultaneously retrieve
  - Temperature upto 200 mb (ECMWF first guess)
  - Water vapor upto 200 mb (ECMWF first guess)
  - Surface Temperature (ECMWF first guess)
  - Dust loading (UMBC first guess)
  - Dust top height (climatological model first guess)
  - Dust effective diameter (4 um first guess)

March 09, 2006 : Area coverage and biases

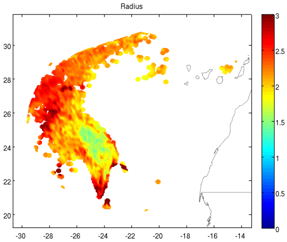
Left plot shows retrieved $\tau(900cm-1)$
Right plot shows biases and std deviations over the channels used

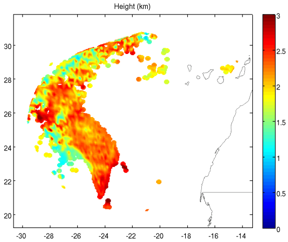




March 09, 2006 : Retrieved Radii and Particle Size

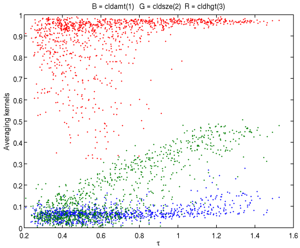
Left plot shows retrieved *reff* (*um*)
Right plot shows retrieved height

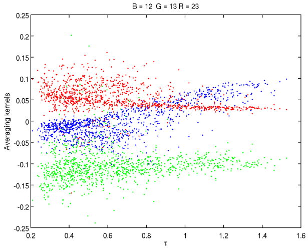




March 09, 2006 : Averaging Kernel vs τ

Left plot shows diagonal (cldamt cldsze cldhgt)
Right plot shows offdiagonol (cldamt/cldsze cldamt/cldhgt cldsze/cldhgt)





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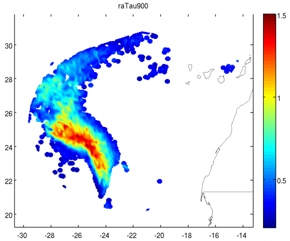
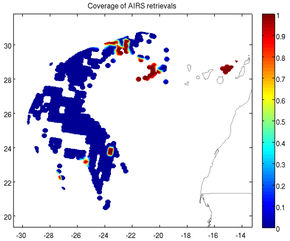
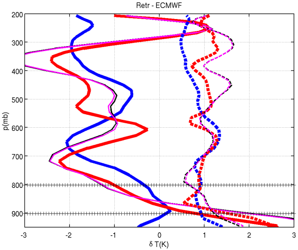
Left plot shows retrieved $\tau(900cm - 1)$
Right plot shows coincident AIRS retrievals (1 = surface quality best or good, 0 = ignore surface quality)
(far fewer FOVs!)

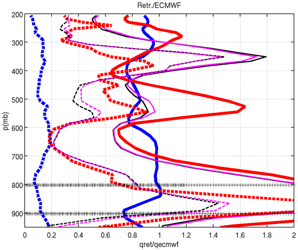




March 09, 2006 : T(z) and Q(z)

Solid = mean, dashed = std deviation
Crosses show the position of the mean dust layer
Blue = UMBC compared to ECMWF
Red = AIRS L2 compared to ECMWF
AIRS L2 is much drier, and a little hotter, at dust top





March 09, 2006 : Stemp and colwater

Histograms of SST differences and col water ratios (upto 200mb)
Blue = UMBC compared to ECMWF
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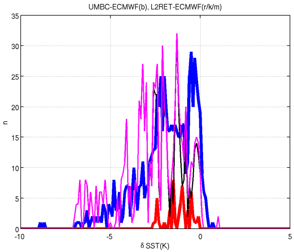
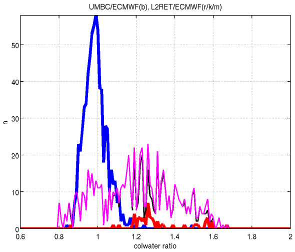
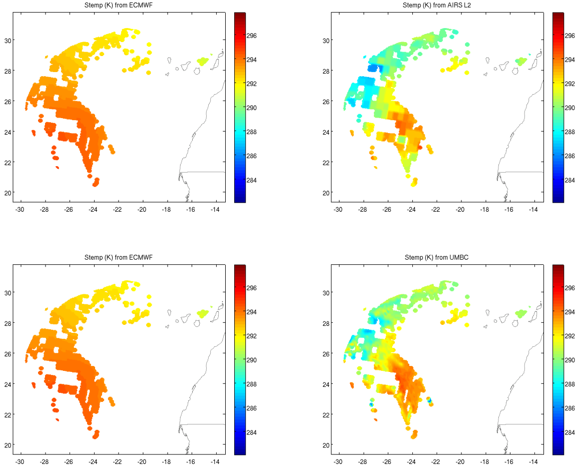
AIRS L2 has higher SST, and is overall drier





March 09, 2006 : Stemp grids

Left = ECMWF, top right = AIRS, bottom right = UMBC



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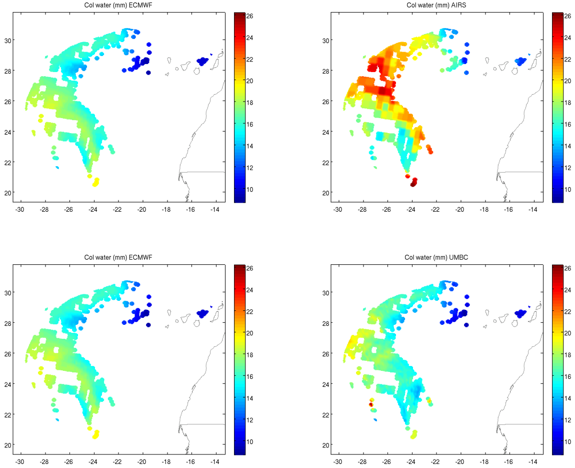

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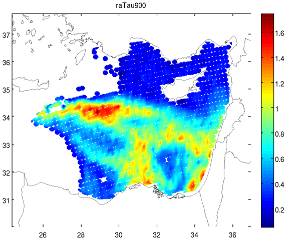

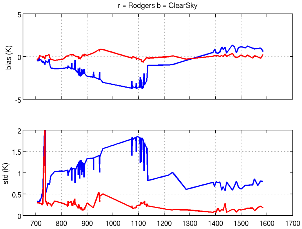

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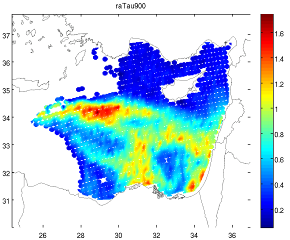

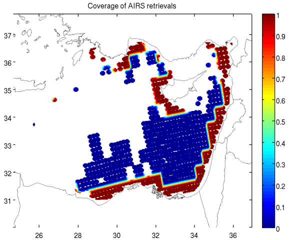

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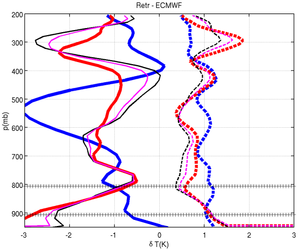

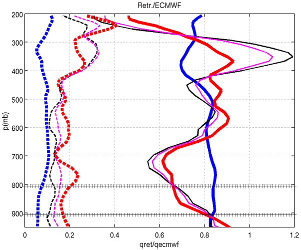

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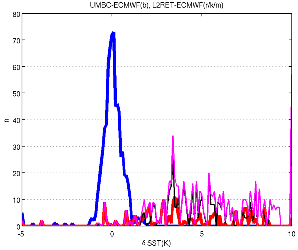

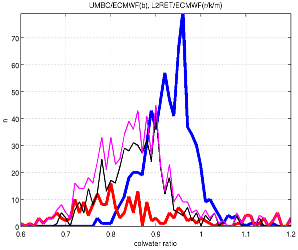

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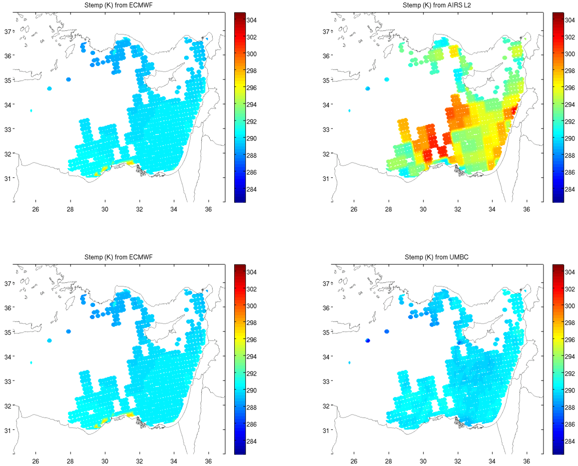

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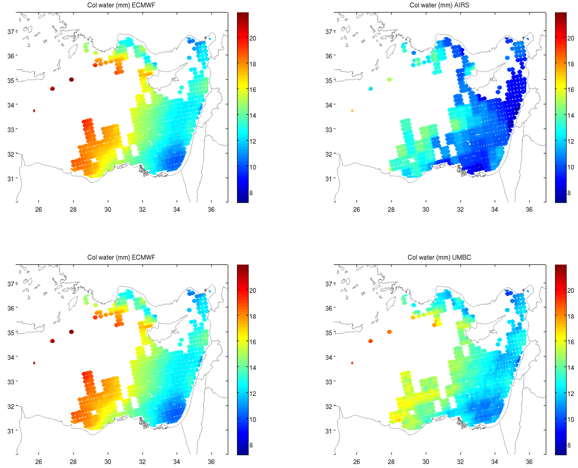
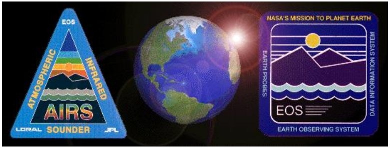


Conclusion

- AIRS L2 quality flag "fails" many dust contaminated FOVs
- Dust contaminated FOVS leads to incorrect L2 retrievals
- Effects could end up in the emissivity, without affecting T(z),Q(z)
- Often the L2 retrievals do not include the lower atm
- The L2 retrievals stemp can be biased either way (+ve or -ve)
- Not shown, but the "clear sky calcs" using L2 retrievals over ocean, strongly resemble dust contaminated radiances!
- UMBC Optimal Estimation Retrievals of T(z),RH(z),dust amount
  Needs to be fine tuned, but first results look promising



OLR calculations

Radiance at the top of a clear sky atmosphere

$$R(\nu,\theta) = \epsilon_s B(\nu, T_s)\tau_{1\rightarrow N}(\nu,\theta) + \sum_{i=1}^{i=N} B(\nu, T_i)(\tau_{i+1\rightarrow N}(\nu,\theta) - \tau_{i\rightarrow N}(\nu,\theta))$$

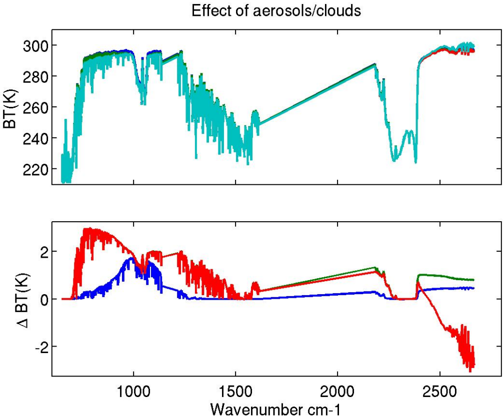
Outgoing Longwave Radiation from top of a clear sky atmosphere
Let $cos(\theta) = \mu$

$$OLR = 2\pi \int_0^\infty d\nu \int_0^1 R(\nu,\mu)\mu d\mu$$

Or directly from AIRS radiances
OLR_forcing = $\Sigma_{i=1}^{2378}(robs_i - rclr_i)\pi$, Extremely FAST!!!!

Outgoing Longwave Radiation and Clouds/Aerosols

Aerosols and clouds affect outgoing radiation
eg look at Tropical Profile with dust and cirrus



OLR forcing for the two duststorms

Histograms of OLR(obs) - OLR(calc)
Left = Feb 24, 2007, Right = Oct 19, 2002
AIRS L2 has "positive" dust forcings while UMBC, ECMWF have negative dust forcings